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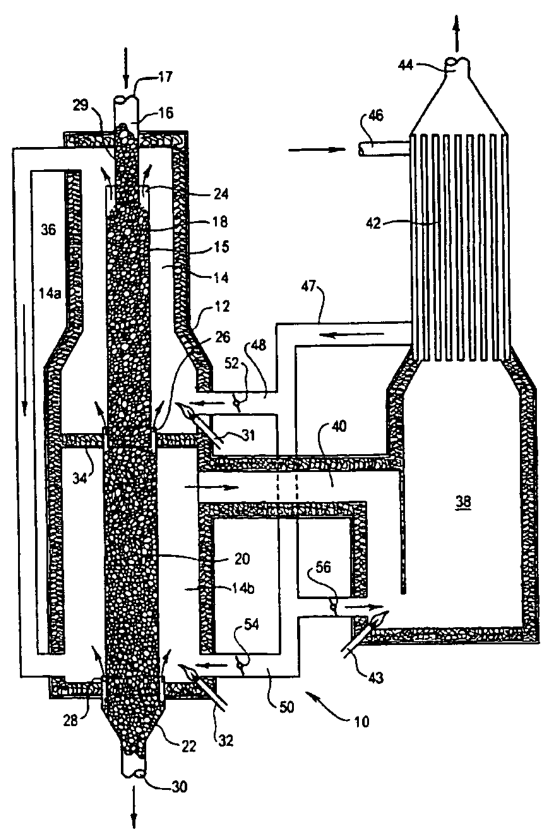

(57) Abstract: A retort (10) including a thermally insulated casing (12) defining a furnace chamber (14) therein; one or more columns (15) provided within said chamber (14), each column (15) comprising a plurality of vertically orientated, vertically spaced, heat resistant tubes (16, 18, 20, 22), wherein the cross-sectional area of each tube is smaller than that of an adjacent, lower tube, and wherein the ends of adjacent tubes are arranged so as to provide an annular space (24, 26, 28) therebetween, an inlet (17) through which a combustible charge is fed into the uppermost tube (16), an outlet (30) from which reacted charge is removed from the lowermost tube (22); and a fluid conduit (36) for conveying combustible volatiles evolved by heating said charge to a gas burning means (31, 32) for combustion, to thereby provide heat to said retort (10).

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RETORT

FIELD OF THE INVENTION

The invention relates to a retort or furnace for use at high temperatures. The invention particularly relates to a retort for use in the pyrolysis of carbonaceous materials, especially low rank carbonaceous materials such as for instance, brown coal, peat, certain soft lignites, anaerobically decomposed plant matter or any combination thereof. The invention may be used to produce char or to produce metals or metal alloys from carbonaceous material-metal composites.

BACKGROUND OF THE INVENTION

Retorts currently used for coal pyrolysis are predominantly horizontal refractory lined vessels operated in a batchwise manner. The vessels are externally heated in various ways until all the volatiles are removed from the brown coal or other carbon containing materials intended for conversion to char. The volatiles produced are often directly discharged to the atmosphere to the obvious detriment of the environment. Alternatively the volatiles may be processed in chemical recovery plants which pose health risks due to the production of carcinogenic compounds, such as for instance phenols, benzpyrenes, etc. There is also a concomitant risk of long lasting soil contamination due to leaks and spillages as well as there being serious waste disposal problems.

While some vertical retorts and shaft furnaces have been previously used in the prior art, they have presented some difficulties. When such retorts are used in coal pyrolysis, for example, gases released during heating and/or pyrolysis of the charge must travel upwards through cooler charge material before being able to escape from the top of the retort. Some of these gases recondense as they encounter the cooler material, which can cause the charge to stick together and obstruct its downward movement. Clearly such problems necessitate minimisation of the volatile content of the charge before it is processed. Such pretreatment complicates and lengthens the overall process. Moreover, some retorts experience oil and tar drop out in low temperature off gas ducts, which is a serious problem.

Furthermore, retorts currently in use are often of heavy and/or cumbersome design, which restricts the type of environments in which they can be used.

There is accordingly a need for a retort which can operate efficiently with minimum obstruction of its charge and which does not require devolatilisation pretreatment of its charge. There is also a need for a retort which minimises the discharge of volatiles and toxic chemicals to the environment. There is furthermore a need for such a retort which is of simple and lightweight design to facilitate its construction and maintenance in remote or inaccessible locations.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a retort including a thermally insulated casing defining a furnace chamber therein;

one or more columns provided within said chamber, each column comprising a plurality of vertically orientated, vertically spaced, heat resistant tubes, wherein the cross-sectional area of each tube is smaller than that of an adjacent, lower tube, and wherein the ends of adjacent tubes are arranged so as to provide an annular space therebetween,

an inlet through which a combustible charge is fed into the uppermost tube,

an outlet from which reacted charge is removed from the lowermost tube; and

a fluid conduit for conveying combustible volatiles evolved by heating said charge to a gas burning means for combustion, to thereby provide heat to said retort.

The present invention also provides a process for producing char by pyrolysis of low rank carbonaceous material, said process including the steps:

(i) forming pellets containing said carbonaceous material,

(ii) feeding said pellets to the inlet of a retort according to the invention,

(iii) operating said retort in order to heat the pellets to a combustion temperature and effect pyrolysis of said pellets to char; and

(iv) removing said char from the outlet of said retort.

The present invention further provides a process for producing metal from carbonaceous material-metal containing composites, said process including the steps:

(i) forming composite bodies containing a mixture of carbonaceous material and metal containing material,

(ii) feeding said composites to the inlet of a retort according to the invention,

(iii) operating said retort in order to heat said composites to a combustion temperature and effect pyrolysis of said carbonaceous material and reduction of the metal containing material.

DETAILED DESCRIPTION OF THE INVENTION

Typically, the retort includes one or more heating means for initiating combustion of said combustible charge.

The retort of the present invention is especially suitable for use in the production of char by the pyrolysis of carbonaceous material, particularly low rank carbonaceous material, such as brown coal. Alternatively, the retort can be used in the production of metal and/or metal alloys from composites of carbonaceous material and metal containing material. The metal containing material typically comprises one or more metal compounds, such as oxides, sulphides, hydroxides, etc. Preferably, the metal compound is a metal oxide. The carbonaceous material is preferably brown coal. The composite is preferably a brown coal-iron oxide composite in a pellet form, in which the carbonaceous material produces reductants upon heating which react with the iron oxide to produce iron and/or steel. The retort of the invention will be described largely with reference to its use in the production of char or metal as set out above. However, it is to be understood that the retort is not restricted to such use.

A key feature of the retort of the invention is the provision of one or more columns, each comprising a succession of vertically spaced heat resistant tubes located inside an internally insulated surrounding shell or casing. The casing is preferably made of steel, more preferably mild steel. The tubes themselves are typically made from a suitable heat and chemical resistant material, such as an alloy, which may contain steel. The distance between the columns of tubes and the shell will vary but should be such as to provide adequate volume for efficient combustion of the heating medium used.

The retort may contain two or more laterally spaced columns, each comprising a succession of vertically spaced tubes, in order to increase the throughput of material treated in the retort.

Preferably the or each column includes three or more vertically orientated, substantially coaxial tubes. These are advantageously vertically spaced from each other such that there is partial overlap between adjacent ends, thereby defining an annular space therebetween. The annular space enables volatiles evolved during heating and/or reaction of the charge to escape therefrom. After the initial start up, combustible volatiles combust at the annuli, thereby providing heat for subsequent reaction of the charge, meaning that the external heating means can be turned down or off.

Preferably each vertical tube is suspended at an end thereof within the retort, allowing free discharge of the charge into the adjacent, lower vertical tube. Moreover free suspension of each tube and the absence of joins between tubes facilitates thermal expansion and contraction of the tubes and reduces failure due to thermal cycling.

The retort preferably comprises two or more combustion zones. A first combustion zone is typically located in an upper region of the retort and a second combustion zone is typically located in a lower region of the retort. Preferably the first and second combustion zones are separated by a wall, and together form a unitary body. More preferably, the wall supports one of the vertically orientated tubes which is suspended therefrom. Preferably, the first and second combustion zone each accommodate one or more vertical tubes, such that each combustion zone has an annulus between tubes opening therein. The provision of more than one combustion zone is advantageous in that it enables greater control over the heating process, as will be subsequently discussed in further detail.

In the first combustion zone, the temperature of the charge is raised causing chemically fixed water to be evolved from the charge. With increasing temperature, low temperature coal volatiles are released, then carbon dioxide is released from any carbonate breakdown. Finally high temperature coal volatiles are released.

In the second combustion zone, the temperature of the charge is raised to a value and for a time sufficient to effect the desired reaction, such as the formation of char or the reduction to metal, as the case may be.

Each combustion zone preferably includes a heating means, more preferably a gas burner. Preferably, each gas burner is located proximate to an

annular space between adjacent tubes. In the case where the charge comprises composite pellets, large amounts of water and low temperature volatiles are evolved during the initial heating. To avoid pellet breakdown during this process, the rate of heating in the first combustion zone is preferably controlled to be relatively low.

In contrast, evolution of high temperature volatiles and completion of reduction reactions need to occur in the second combustion zone, and accordingly higher temperatures are required therein. The provision of a wall between the combustion zones assists to maintain relatively lower temperatures in the first combustion zone and relatively higher temperatures in the second combustion zone. However to avoid excessively high temperatures in the second combustion zone, which can adversely affect product quality and/or damage equipment, it may be necessary to operate under fuel-rich conditions.

Preferably, the high temperature coal volatiles and reducing gases evolved from the charge in the second combustion zone are released via an open annulus into the first combustion zone where they are mixed with air and burnt to provide heat. An external heating means, such as an LPG burner is preferably provided in each combustion zone to provide ignition and to assist with start up of the combustion. Once the combustion reaction has commenced, the burners can be run as pilot burners on minimum gas flow to prevent flame failure.

The calcination reactions in the first combustion zone typically evolve water, low temperature coal volatiles and carbon dioxide. These gases mix with partially combusted gases from the charge and then pass to the second combustion zone, where they are mixed with air and completely combusted to produce heat. As previously stated, the initial start up energy in the second combustion zone may be provided by an LPG burner, whose supply of gas is turned down or off once combustion gases are generated in the primary combustion zone.

The greatest proportion of volatiles released from the dry carbonaceous material is released in the temperature range 300 to 400°C, which typically occurs in the first combustion zone. These volatiles mostly travel downwards to an annular space, which means that they pass through material of increasing temperature, thereby preventing the prior art problem of recondensation of the

volatiles. Similarly, high temperature tar vapours, if present, tend to be released in the temperature range of 650 to 750°C, typically in the second combustion zone. These vapours also mostly travel downwards to an annular space through material of increasing temperature which prevents their recondensation.

The retort preferably further includes a heat exchanger or recuperator. Hot waste gases from the second combustion zone are passed into the heat exchanger where heat is transferred to incoming combustion air before being passed into the first and/or second combustion zones.

At the base of the retort is provided a discharging means for removing the reacted charge from the lowermost tube. Typically such discharging means comprises a rotary discharge valve which may feed into a chute.

The retort may additionally include a third combustion zone into which pass residual combustible gases exhausted from the second and possibly first, combustion zones. The third combustion zone also preferably includes a heating means, more preferably a gas burner. These residual combustible gases are burnt in the third combustion zone before they pass into the heat exchanger and vented to atmosphere. The gases thereby exhausted are low in greenhouse gases. The need for a third combustion zone may arise, for instance, where the second combustion zone is operated under fuel rich conditions and accordingly gases exhausted therefrom still contain significant quantities of combustibles.

The column/s of tubes need not be actually housed in the third combustion zone. While the first and second combustion zones preferably together form a unitary body, the third combustion zone may be a separate unit to the first and second combustion zones, which is linked thereto via a fluid conduit.

The retort may advantageously also include an integral metal melting unit. If present, the melting unit typically communicates with the outlet of the furnace chamber, such that the composite pellets are fed thereto after being reduced. Preferably, the melting unit is located vertically below the outlet of the furnace chamber such that the reduced pellets are automatically and continuously fed into the melting unit under gravity.

The melting unit preferably includes an insulated melting chamber for receiving the reduced pellets. Once in the melting unit, the temperature of the

reduced pellets is raised sufficiently to effect melting of the metal. This may be achieved by simple combustion of the carbonaceous material remaining in the reduced pellets, possibly aided by injection of an oxidising gas through pipes or tuyeres. If necessary, additional fuel may also be added at this time, for example combustible gases and/or solid materials. Preferably, the oxidising gas is preheated, such as by heat exchange with waste gases from the retort, and typically comprises air or some other oxygen containing gas.

Advantageously, the temperature increase in the melting unit is augmented by employing an external heating means. Preferably, the external heating means is an electrical heating means, such as an induction heater, resistance heater or a submerged arc. An induction heater is particularly preferred. In the case of an induction heater, the wall of the insulated melting chamber typically accommodates a conductor coil, with the metal to be melted forming the secondary of a transformer. An induction heater can be used alone or in conjunction with the oxidising gas assisted combustion.

The melting unit preferably further includes two outlets : one for slag discharge and one for molten metal discharge. The slag outlet is typically located higher than the molten metal outlet.

When the metal melting unit includes an induction heater, the particular arrangement of slag and molten metal outlets can determine whether the metal melting unit is used in a continuous or batch mode. The location of the metal outlet towards the bottom of the melting chamber, below the conductor coil, typically requires the melting unit to be operated in batch mode. This is because the reservoir of molten metal within the melting chamber can be completely emptied. As the metal reservoir forms the secondary of a transformer, its intermittent discharge means that the induction heater cannot be continuously operated. In contrast, the location of the metal outlet towards the top of the melting chamber, and above the conductor coil, ensures that the chamber will always contain a reservoir of molten metal and enable uninterrupted, continuous operation of the induction heater.

An advantage of the present invention is a retort of light weight and simple design, enabling relatively inexpensive construction and maintenance which particularly facilitates its use in remote or inaccessible locations. Another advantage is that the retort enables high efficiency continuous operation with

minimal recondensation of off-gases. Moreover, internal combustion of off-gases provides a source of heat and external heating by any desired means selected, is largely only needed in the start-up operation. Further, the controlled two to three stage combustion of particular embodiments ensures high thermal efficiency and low levels of greenhouse emissions, such as CO and NO_x.

Advantages of the embodiment of the invention including a metal melting unit are:

(i) Simple gravity flow feed of material from the furnace chamber to the melting chamber, requiring no control system between the two chambers. The feed rate of material through the retort can be simply controlled by the output from the melting chamber.

(ii) Maximised thermal efficiency - the heat and chemical composition of the waste gases evolved from the melting chamber can be used in the reduction of pellets before they enter the melting chamber. The gases can be then fully combusted and oxidised to carbon dioxide in the third combustion chamber before passing to the heat exchanger where heat is recovered. Accordingly, the final gas discharge has a relatively low temperature of around 350°C and virtually no carbon monoxide. This compares very favourably with a set up in which melting takes place in a separate melting chamber where waste gas would be expected to have a temperature of around 1500°C or higher and a high carbon monoxide content.

(iii) The transfer of waste heat from the melting chamber to the furnace chamber means a higher temperature of reduction. This allows more carbon to be taken into solution in the steel product and allows a greater chance for sulphur removal by reaction with the calcium and magnesium in the feed pellets.

DESCRIPTION OF DRAWINGS

Figure 1 is a vertical cross-section through a first embodiment of a retort according to the invention.

Figure 2 is a vertical cross-section through a second embodiment of a retort according to the invention.

Figure 3 is a cut-away vertical cross-section through the basal portion of a third embodiment of a retort, showing the details of a batch metal melting unit.

Figure 4 is a cut-away vertical cross-section through the basal portion of a fourth embodiment of a retort, showing the details of a continuous metal melting unit.

Referring to Figure 1, a retort 10 includes a thermally insulated metal shell or casing 12 defining therein an annular furnace chamber 14. The furnace chamber 14 houses a column 15 of heat resistant tubes 16, 18, 20 and 22 which are vertically orientated and vertically spaced from each other. The cross-sectional area of the tubes 16, 18, 20 and 22 increases in going from the top of the retort 10 to its bottom. Accordingly, the relative cross-sectional area of the tubes is as follows tube 16 < tube 18 < tube 20 < tube 22.

The respective ends of adjacent tubes overlap to thereby form open annular spaces 24, 26, 28 therebetween.

The uppermost tube 16 includes an inlet 17 and accordingly acts as a feeder tube through which the charge material 29 is fed into the retort 10. The charge moves through the tubes 16, 18, 20 and 22 in succession under the force of gravity. An outlet 30 is provided at the bottom of the lowermost tube 22 through which the reacted charge 29 is removed from the retort 10.

The furnace chamber 14 is divided into first and second combustion zones comprising first and second chambers 14a and 14b, respectively, by a transverse wall 34. The combustion chambers 14a and 14b each include a heating means comprising a gas burner 31, 32 respectively which provide an initial heat source for raising the temperature of the charge 29. The gas burner 32 in the combustion zone 14b is larger than burner 31 in order to provide sufficient heat for commencement of combustion.

A fluid conduit 36 extends from the top of chamber 14a to the base of chamber 14b. Gases evolved from heating the charge 29 are evolved from open annuli 26 and 24 and travel through the conduit 36 to the chamber 14b, where they are combusted.

The retort 10 further includes a third combustion chamber 38 communicating with the second combustion chamber 14b via a conduit 40. The third combustion chamber 38 in turn communicates with a recuperator 42 through which exhaust gases pass to exhaust outlet 44 under operation of an

exhaust fan (not shown). A gas burner 43 is provided inside the third combustion chamber 38. A damper 56 regulates the amount of combustion air fed to the gas burner 43.

The recuperator 42 includes an inlet 46 through which is admitted atmospheric air under action of a fan (not shown), and an outlet 47 through which preheated air exits. In the recuperator 42, the heat from the exhaust gases is transferred to the incoming air to thereby preheat it and the preheated air enters the first and second chambers 14a and 14b via fluid conduits 48 and 50, respectively. The amount of air flowing into the chambers 14a and 14b can be regulated by dampers 52, 54 respectively.

An example of the operation of the retort 10 will now be described. A cold charge 29 of composite pellets comprising a homogeneous mixture of brown coal and iron oxide fines is fed into the top of retort 10 via inlet 17 of feeder tube 16. Combustion air is introduced to chambers 14a, 14b and 38 by adjusting the dampers 52, 54 and 56, respectively. In order to initiate combustion, burners 31, 32 and 43 are then lit using an external source of LPG gas as fuel. The largest burner 32 is adjusted to its maximum firing rate.

As the pellets in the lower part of the retort begin to heat up, moisture and low temperature coal volatiles are emitted from annular space 28. Combustion of the coal volatiles in turn increases the heating rate. As waste gases travel through the recuperator 42, incoming combustion air is heated, which in turn further increases heating rate.

With increasing temperature, evolution of water vapour and coal volatiles from the charge 29 commences from annular space 26. The gas burner 31 ignites the coal volatiles, thereby heating the pellets in the upper part of the retort 10. Water vapour and low temperature coal volatiles are in turn emitted from annular space 24. These, together with waste gases resulting from combustion at annular space 26, travel from combustion chamber 14a along conduit 36 to combustion chamber 14b. There the volatiles are mixed with incoming preheated air introduced via inlet conduit 50 and combusted in chamber 14b, further increasing the temperature of the charge 29.

As the pellets dry, devolatilise, calcine and reduce, they shrink in size. Furthermore, the brown coal in the pellets is non-caking. These two factors

ensure that the pellets fall freely through the parallel sided tubes without bridging and hold-ups.

With increasing temperature in chamber 14b, the temperature of the charge is raised sufficiently for reduction of the iron oxide to occur. Hot reduced pellets can be removed from the lowermost tube 22 via outlet 30. Simultaneously, the charge 29 is replenished by addition of further pellets to inlet 17.

At this stage, the burner 32 may be turned off, or preferably down, to a pilot setting. The other two burners 31 and 43 may also be adjusted to pilot settings at this stage. Preferably the exhaust and combustion air fans (not shown) are adjusted to give a slight negative pressure in the chambers 14a and 14b to prevent leakage of waste gas therefrom. Temperature regulation in chambers 14a, 14b and 38 is achieved by adjusting the dampers 52, 54, 56, respectively, to control the amount of combustion air entering those chambers (e.g., reducing the flow of combustion air reduces temperature).

At this stage, the retort 10 is in a continuous operating mode. The charge 29 can be continuously replenished by feeding further pellets into the inlet 17. As the charge 29 descends under gravity through the column 15, it increases in temperature. In the combustion chamber 14a, the charge is preheated and calcined. There, water is first evolved via annular space 24. With further increase in temperature, low, then medium temperature coal volatiles are driven off and escape via annular spaces 24 and 26.

After entering the second chamber 14b, the pellets are maintained at a sufficiently high temperature and for a sufficient length of time to effect the desired level of reduction. High temperature volatiles and gaseous products from the reduction, and other, reactions are released which escape from annular space 28 and to a lesser extent, annular space 26. Those gases leaving annular space 26 are mixed with controlled amounts of combustion air entering via damper 52 and partially burnt to provide heat for chamber 14a. Waste gases from this combustion combine with gases leaving annular space 24 and are ducted down conduit 36 to the bottom of chamber 14b. These gases are mixed with gases leaving annular space 28 and combusted with sufficient combustion air to achieve the required temperature in the combustion chamber 14b. Any waste gases from the combustion travel via conduit 40 to

the third combustion chamber 38, where they are combusted with an excess of combustion air thereby ensuring complete reaction of the waste gases to provide a substantially clean effluent. The effluent is discharged from gas outlet 44 via a recuperator 42, where heat from the effluent gas is transferred to incoming atmospheric air entering via inlet conduit 46.

Most of the volatiles released in the first combustion zone travel downwards to escape from annular space 26, meaning that they pass through material of increasing temperature. This substantially prevents the prior art problem of recondensation of the volatiles. Moreover, upon escape from annular space 26, the volatiles are immediately contacted with combustion air, entering via conduit 48, and partially burnt, thereby further raising their temperature and further preventing recondensation. Recondensation of gases escaping from annular space 24 is largely avoided due to their immediate mixing with the hot combustion gases they encounter in combustion chamber 14a.

Where high temperature tar vapours are present in the charge 29, they tend to be released in the temperature range 650 to 750°C, which is typically in the second combustion zone. The tar vapours also tend to travel downwards, to the annular space 28, through material of increasing temperature, thereby substantially preventing recondensation of those vapours.

It has been found that the reduction of iron oxide in the retort 10 can occur therein at the relatively low temperature of 950°C. By contrast, conventional bath smelting processes would require a temperature around 1500°C. The high temperatures reached in the second chamber 14b (and third chamber 38, if needed) ensure that the reactions therein are maintained at sufficiently high temperatures that the effluent gases meet environmental requirements.

A second embodiment of the retort of the invention is illustrated in Figure 2. The second embodiment 110 is essentially similar to the first embodiment and like reference numerals accordingly refer to like parts.

The main difference between the second embodiment and the first embodiment is that the second embodiment includes an integral metal melting unit 158 which communicates with the outlet 130 of the furnace chamber 114 via a conduit 162. The outlet 130 is provided at the lowermost part of an

integral funnel shaped section 160 at the base of the chamber 114. Accordingly, the funnel shaped section 160 performs essentially the same function as the lowermost tube 22 of the first embodiment in that the gap 128 between the bottom of tube 120 and the funnel shaped section 160 allows evolved gases to escape from the charge for combustion, similarly to the open annulus 28 of the first embodiment 10.

The integral metal melting unit 158 includes an insulated melting chamber 164 with pipes or tuyeres 166,168 extending into the melting chamber 158. A hot, oxidising gas, such as air or oxygen, is injected into the melting chamber 158 through the tuyeres in order to combust carbonaceous material in the pellets and raise the temperature sufficiently to effect melting of the metal therein. The hot oxidising gas is heated by means of heat exchange with waste gases expelled from furnace chamber 114. This is effected in an additional heat exchanger 167 placed in between the third combustion chamber 138 and the recouperator 142. However, it is to be understood that the arrangement of the recouperator 142 and the heat exchanger 167 may instead be reversed, with the recouperator 142 placed intermediate the third combustion chamber 138 and the additional heat exchanger 167, or the heat exchanger 167 and the recouperator 142 can be placed in parallel.

The melting chamber 158 is provided with two outlets : a first, slag outlet 170 located a short distance below the tuyeres 166,168 and for the removal of a slag phase and a second, molten metal outlet 172 located below the slag outlet 170, for the removal of a molten metal phase. Accordingly, in use, the hot reduced pellets are fed into the top of the melting chamber 158 whereupon hot air, or hot oxidising gas, is injected into the melting chamber to combust carbonaceous material in the pellets and raise the temperature of the pellets to the melting temperature of the metal. A slag phase may form on top of the molten metal phase. Any slag phase which forms is removed via outlet 170, which can be closeable by any suitable means, (in this case by moist fireclay plugs). The molten metal is removed via lower outlet 172, which again may be closeable by any suitable means, such as moist fireclay plugs.

Hot gases produced in the melting chamber 158 include a high proportion of carbon monoxide. These gases travel upwardly through the hot pellets in the conduit 162 and the funnel shaped section 160, thereby enhancing

the reduction of the pellets before they enter the melting chamber 158, and supplying further heat to the furnace chamber 114. The gases then join the other waste gases from the first and second combustion chambers 114a and 114b.

A third embodiment of the retort 210 is illustrated in Figure 3 which, for simplicity, illustrates the basal area of the retort 210 only. Again the third embodiment 210 is essentially similar to the second embodiment 110 and accordingly, like reference numerals refer to like parts.

It will be noted from the cut-away portion of the second combustion chamber 214b that the retort 210 includes two columns 215a and 215b of heat resistant tubes, of which only the respective lowermost tubes 220a and 220b are visible. Each of the columns 215a and 215b are arranged in the same manner as column 115 in the second embodiment (refer to Figure 2).

The third embodiment is similar to the second embodiment in that the third embodiment also includes an integral metal melting unit 258. However, the integral metal melting unit 258 differs from unit 158 in that it comprises an induction heater 276 housed in an insulated melting chamber 264. Induction heaters are commonly used in the foundry industry and it will therefore not be necessary to further explain their operation.

The integral metal melting unit 258 is located at the outlet 230 of the furnace chamber 214. The outlet 230 is provided at the lowermost point of an integral funnel shaped section 260 of the furnace chamber 214. The funnel shaped section 260 directs the reduced charge from the furnace chamber 214 into the melting unit 258 via the outlet 230. The gap 228 between the bottom of tube 220 and the funnel shaped section 260 allows evolved gases to escape from the charge as it enters the melting unit 258, which gases are combusted in the chamber 214.

The provision of an integral metal melting unit 258 at the base of the retort 210 is advantageous for a number of reasons. One reason is that the feed of reduced charge into the metal melting unit 258 is automatically and continuously achieved under gravity by virtue of the melting unit 258 being located vertically underneath the outlet 230 of furnace chamber 214.

The use of an induction heater 276 in the metal melting unit 258 is also advantageous. An induction heater 276 provides better control of temperature

in the melting unit 258 as compared with a melting unit relying solely on combustion, such as melting unit 158 of the second embodiment herein. The use of the induction heater 276 also facilitates start up of the retort of 210.

Moreover, the use of an induction heater 276 enables higher levels of metal refining, by virtue of being able to maintain high temperatures in the metal melting unit 258 for extended periods of time. Under such conditions, impurity removal from molten iron is optimised, especially removal of sulphur, typically by reaction with calcium oxide to produce calcium sulphate. Also, carbon solubility in the iron melt is favoured, thereby enhancing reducing conditions in the melt and permitting retention of desirable species having a strong affinity for oxygen. One such species is magnesium, which is typically easily oxidised.

The integral metal melting unit 258 also includes an upper, slag outlet 270 and a lower, molten metal outlet 272. The slag outlet 270 is located above the induction heater 276 and the metal outlet 272 is located below it. In use, once the reduced charge is melted in the metal melting unit 258, any slag phase which forms on top of the molten metal phase is tapped off via the slag outlet 270. The molten metal phase is tapped off via molten metal outlet 272. Both the slag and metal outlets 270, 272 can be closed by removable, moist fireclay plugs.

The arrangement of slag and metal outlets 270, 272 requires that metal melting unit 258 be operated in a batch mode. This is because the induction heater 276 requires the chamber 274 of the metal melting unit 258 to contain metal which forms the secondary of a transformer, thereby allowing the induction heater 276 to operate. When the chamber 274 is empty, after the molten metal is tapped off, the induction heater 276 cannot operate.

A fourth embodiment of a retort 310 having an integral metal melting unit which operates in a continuous mode is illustrated in Figure 4. Only the basal area of the retort 310 is shown in Figure 4 for simplicity. The fourth embodiment is essentially similar to the third embodiment in Figure 3 and, again, like reference numerals will refer to like parts. For brevity, only those features which differ from the third embodiment will be discussed herein.

The retort 310 includes pipes or tuyeres 366, 368 extending into the chamber 374 of the metal melting unit 358. The tuyeres 366, 368 operate similarly to the tuyeres 166, 168 of the second embodiment, with a hot,

oxidising gas being injectable therethrough in order to combust carbonaceous material in the charge. The hot oxidising gas may be heated by means of heat exchange with waste gases from furnace chamber 314 using a similar set up as that described in relation to the second embodiment.

As mentioned, the metal melting unit 358 is operable in a continuous manner. This is achieved by the location of both the slag and metal outlets 370, 372 above the induction heater 376. This arrangement ensures that the chamber 374 will always contain a metal phase, and typically a slag phase also, at least up to the level of the inlet 378 of the conduit 380 linking the chamber 374 with slag and metal outlets 370, 372. The continual presence of a metal phase in chamber 374 provides the secondary of a transformer, thereby allowing continuous operation of the induction heater 376 and, consequently, continuous operation of the retort 310 (subject to continued throughput of feed).

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

CLAIMS:

1. A retort including a thermally insulated casing defining a furnace chamber therein;

one or more columns provided within said chamber, each column comprising a plurality of vertically orientated, vertically spaced, heat resistant tubes, wherein the cross-sectional area of each tube is smaller than that of an adjacent, lower tube, and wherein the ends of adjacent tubes are arranged so as to provide an annular space therebetween,

an inlet through which a combustible charge is fed into the uppermost tube,

an outlet from which reacted charge is removed from the lowermost tube; and

a fluid conduit for conveying combustible volatiles evolved by heating said charge to a gas burning means for combustion, to thereby provide heat to said retort.

2. The retort of claim 1, further including one or more heating means for initiating combustion of said combustible charge.

3. The retort of claim 1 or 2, wherein the ends of adjacent tubes overlap to define said annular space.

4. The retort of any preceding claim, wherein said tubes are made from a heat and chemical resistant alloy containing steel.

5. The retort of any preceding claim, wherein the or each chamber includes three or more vertically orientated, substantially coaxial tubes.

6. The retort of any preceding claim, wherein each vertical tube is suspended at an end thereof such as to allow free discharge of said charge from an upper tube into an adjacent lower tube.

7. The retort of any preceding claim, having no joins between tubes thereby facilitating thermal expansion and contraction and minimising failure of the tubes due to thermal cycling.

8. The retort of any preceding claim, including first and second combustion zones, wherein said first combustion zone is located in an upper region of the retort and said second combustion zone is located in a lower region of the retort.

9. The retort of claim 8, wherein said first and second combustion zones are separated by a wall and together form a unitary body.

10. The retort of claim 9, wherein one of said tubes is supported by and is suspended from said wall.

11. The retort of any one of claims 8 to 10, wherein each of said combustion zones accommodates one or more of said vertical tubes such that a respective annulus between adjacent tubes opens into each combustion zone.

12. The retort of any one of claims 8 to 11, wherein each said combustion zone includes a heating means.

13. The retort of claim 12, wherein said heating means is a gas burner.

14. The retort of claim 12 or 13, wherein each said heating means is located proximate to a respective said annular space.

15. The retort of any one of claims 8 to 14, further including a gaseous conduit between said first and second combustion zones.

16. The retort of any one of claims 8 to 15, further including a third combustion zone for combusting residual combustible gases exhausted from the second an/or first combustion zones.

17. The retort of any one of claims 8 to 16, further including a heat exchanger into which hot waste gases from one or more combustion zones are passed to heat incoming gases.

18. The retort of any preceding claim further including a discharge means for removing reacted charge from the lowermost tube.

19. The retort of any preceding claim, further including an integral metal melting unit downstream of the second combustion zone.

20. The retort of claim 19, wherein said integral metal melting unit is located vertically below said second combustion zone.

21. The retort of claim 19 or 20, wherein said metal melting unit includes an insulated melting chamber heated by combustion of carbonaceous material in the reacted charge fed thereto.

22. The retort of claim 21, wherein said insulated melting chamber is further heated by an induction heater.

23. The retort of claim 21 or 22, further including pipes or tuyeres for injecting a hot oxidising gas therethrough into said melting chamber.

24. The retort of claim 22 or 23, wherein said integral metal melting unit further includes a slag outlet and a molten metal outlet.

25. The retort of claim 24, wherein said molten metal outlet is located towards the bottom of the molten metal reservoir in the melting chamber and said integral metal melting unit is operable in batch mode.

26. The retort of claim 24, wherein said molten metal outlet is located towards the top of the molten metal reservoir in the melting chamber and said integral metal melting unit is operable in continuous mode.

27. A process for producing char by pyrolysis of low rank carbonaceous material, said process including the steps:

(i) forming pellets containing said carbonaceous material,

(ii) feeding said pellets to the inlet of a retort according to any one of claims 1 to 26,

(iii) operating said retort in order to heat the pellets to a combustion temperature and effect pyrolysis of said pellets to char; and

(iv) removing said char from the outlet of said retort.

28. A process for producing metal from carbonaceous material-metal containing composites, said process including the steps:

(i) forming composite bodies containing a mixture of carbonaceous material and metal containing material,

(ii) feeding said composites to the inlet of a retort according to any one of claims 1 to 26,

(iii) operating said retort in order to heat said composites to a combustion temperature and effect pyrolysis of said carbonaceous material and reduction of the metal containing material.

29. The process of claim 28, further including the step:

(iv) feeding the reduced composites to the metal melting unit of the retort defined in any one of claims 19 to 26 and heating said composites to the temperature of melting of said metal.

30. The process of claim 28 or 29, wherein said metal is iron.

31. A retort, substantially as herein described with reference to any one of the embodiments shown in the accompanying drawings.

32. A process for producing metal from carbonaceous material-metal containing composites substantially as herein described with reference to the accompanying drawings.

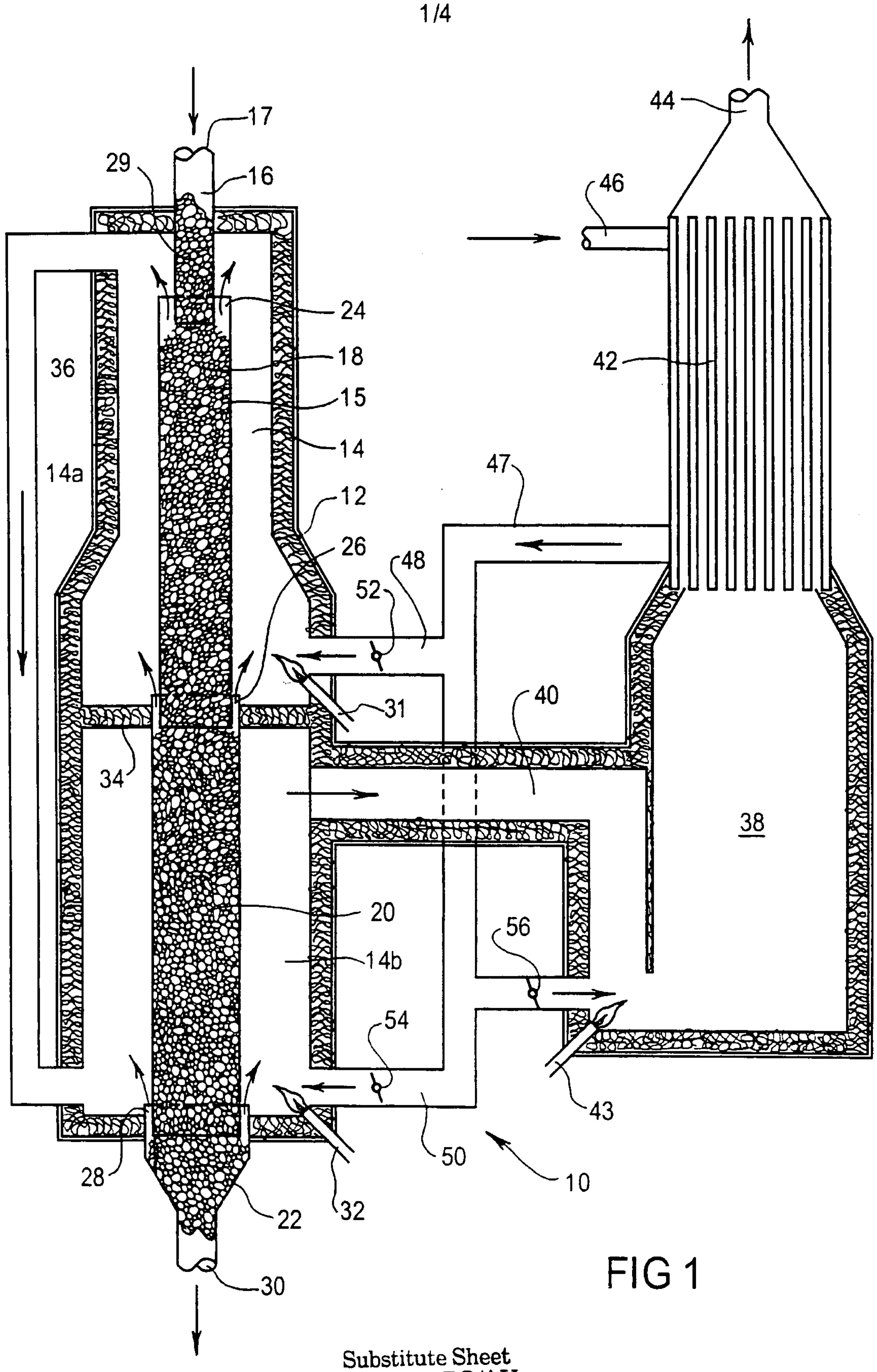
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FIG 1

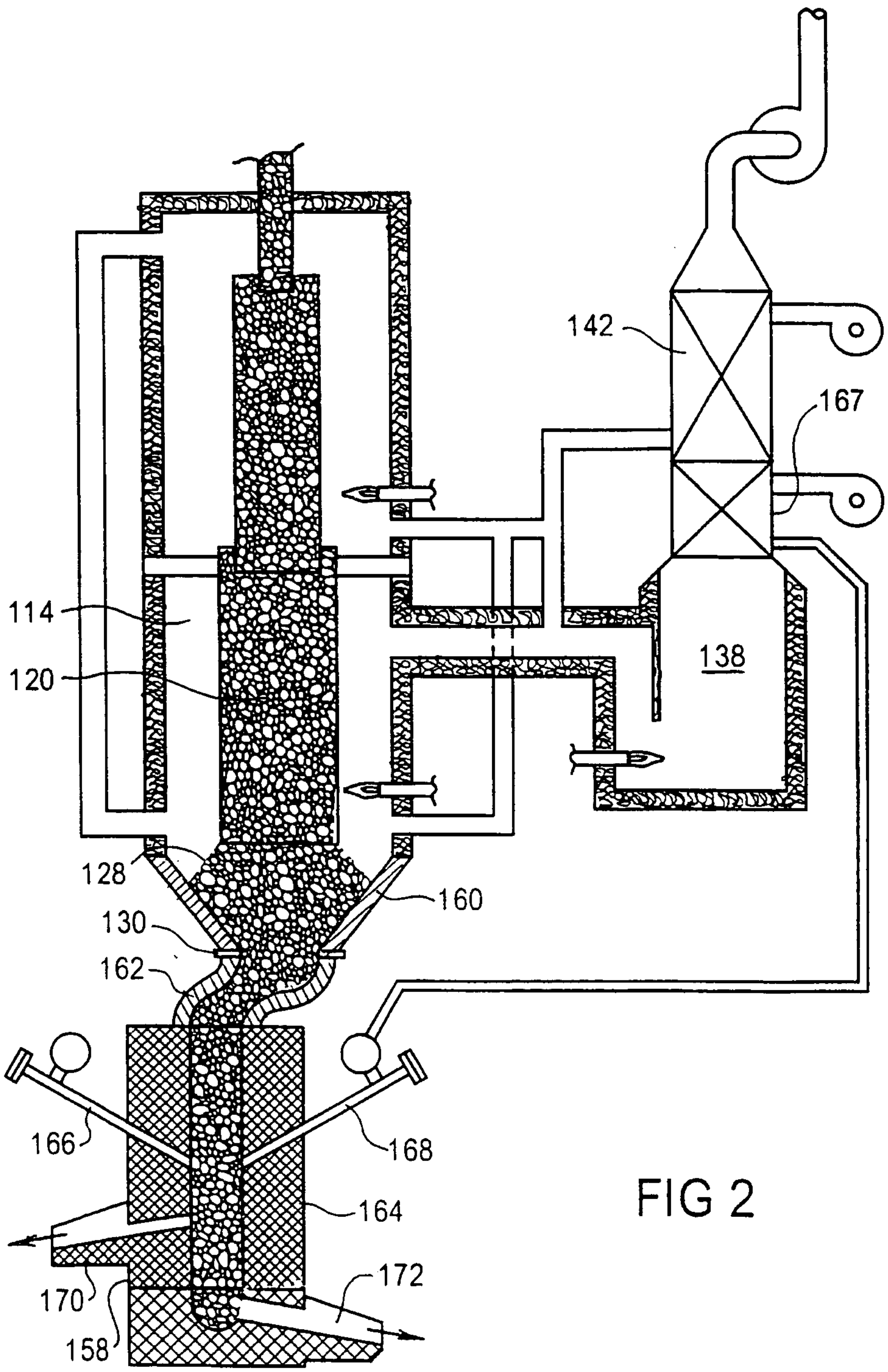

FIG 2

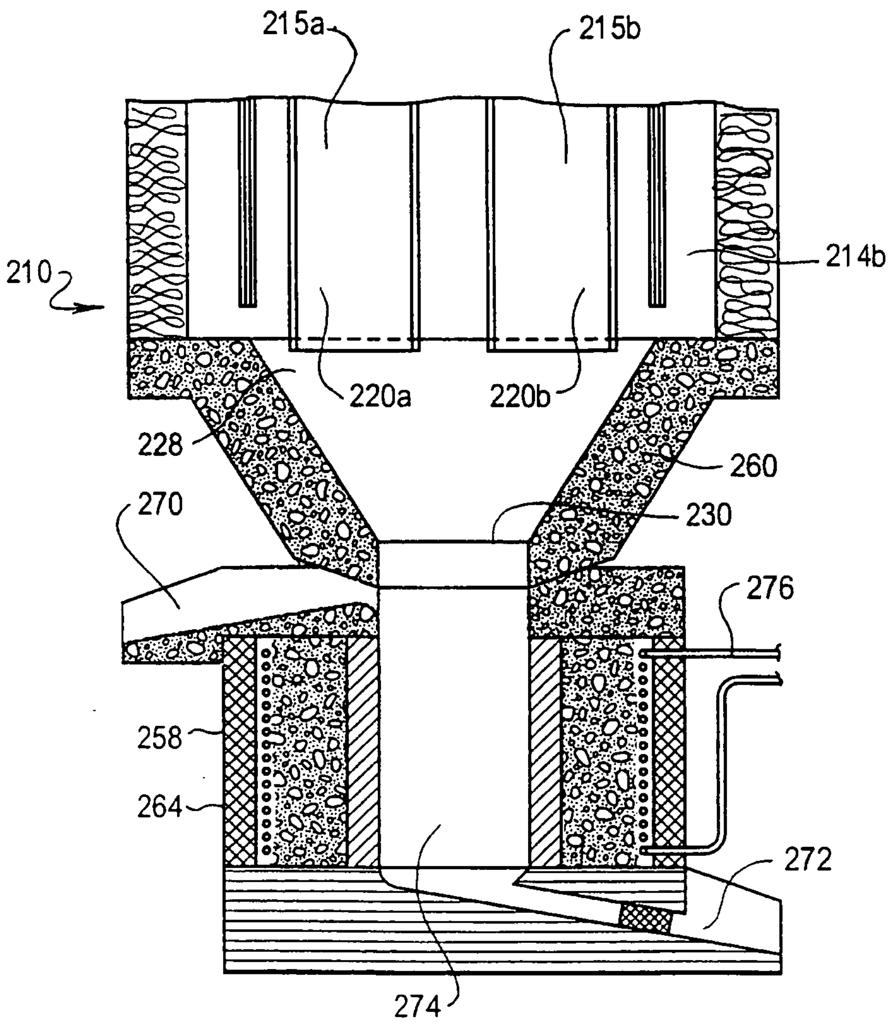
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FIG 3

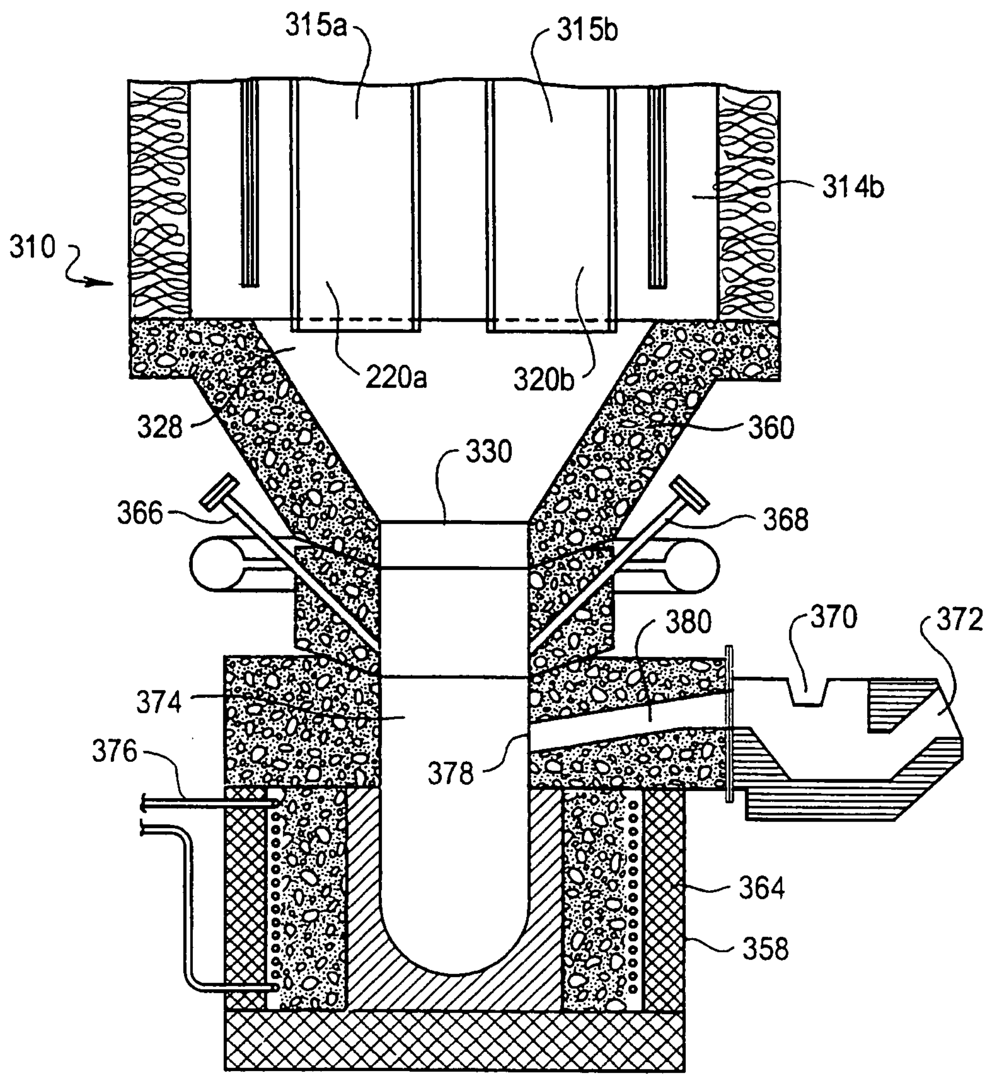
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FIG 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/01427

A.	CLASSIFICATION OF SUBJECT MATTER
Int. Cl. [7]:	C10B 47/18; C21B 11/00; F27B 5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10B 47/18, C10B 1/04; C21B 11/00; F27B 5/06, 5/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU:IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: PYROLYS+ or CARBONI+ or COKI+ or DISTIL+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4732 368 A (Pusateri et al.) 22 March 1988	
A	US 4619 738 A (Lewis et al.) 28 October 1986	
A	US 3963 415 A (Albright) 15 June 1976	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 January 2001	25 January 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer JOHN DEUIS Telephone No : (02) 6283 2146

INTERNATIONAL SEARCH REPORT

International application No. PCT/AU00/01427

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4399 846 A (De Souza Dias et al.) 23 August 1983	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/01427

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4732368	AU	65309/86	BE	905775	CA	1294132
		DE	3639343	FR	2591234	GB	2185042
		JP	62130230	US	4654077		
US	4619738	US	4601811				
US	3963415	AU	10166/76	BE	837447	BR	7600460
		CA	1063805	DE	2600643	ES	444175
		ES	447436	FR	2297179	GB	1529923
		IN	145056	JP	51095402	TR	19193
		ZA	7507409				
US	4399846	AU	65150/80	BR	8002400	ES	499496
		ES	8201630	FR	2480722	GB	2074139

END OF ANNEX